

What is claimed is:

1. A method for measuring a flow rate of a fluid moving in a tube which comprises the steps of:

5 (1) preparing a flowmeter comprising a set of a first upstream side shock wave-generating piezoelectric element and a first downstream side shock wave-receiving piezoelectric element and a set of a second downstream side shock wave-generating piezoelectric element and a
10 second upstream side shock wave-receiving piezoelectric element arranged on a surface of the tube under such condition that the shock wave-generating piezoelectric element and the shock wave-receiving piezoelectric element of each set are arranged along a fluid-moving direction
15 apart from each other at an equivalent distance;

(2) causing movement of the fluid in the tube and, while the fluid is moving, an impulse voltage with steep rising edge or steep falling edge is applied to the first shock wave-generating piezoelectric element to generate a
20 shock and transmit the shock through a wall of the tube into the moving fluid so as to produce a shock wave in the moving fluid;

(3) transmitting the shock wave through the moving fluid and receiving the transmitted shock wave by the
25 first shock wave-receiving piezoelectric element through the wall of the tube;

(4) while the fluid is moving, an impulse voltage with steep rising edge or steep falling edge is applied to the second shock wave-generating piezoelectric element
30 to generate a shock and transmit the shock through the

wall of the tube into the moving fluid so as to produce a shock wave in the moving fluid;

(5) transmitting the shock wave generated in the step (4) through the moving fluid and receiving the
5 transmitted shock wave by the second shock wave-receiving piezoelectric element through the wall of the tube;

(6) processing data of the wave received in the step (3) and data of the wave received in the step (5) to obtain data of a composite wave and detecting a predeter-
10 mined characteristic value from the data of the composite wave;

(7) preparing a relationship between a moving rate of the fluid and the same characteristic value of data of a composite wave corresponding to the moving rate sepa-
15 rately;

and

(8) comparing the characteristic value of data of the composite wave obtained in the step (6) with the relationship obtained in the step (7), to calculate the
20 flow rate of the fluid of the step (2).

2. The method of claim 1, wherein the voltage applied by the impulse voltage in the steps (2) and (4) is constant until the generation of the shock in the
25 shock wave-generating piezoelectric element ceases.

3. The method of claim 2, wherein the voltage applied by the impulse voltage in the steps (2) and (4) is kept constant until the shock wave-receiving piezo-

electric element receives the shock wave in the steps (3) and (5).

4. The method of claim 1, wherein the processing
5 for obtaining the data of the composite wave in the step (6) is performed by obtaining a difference between the data of the wave received in the step (3) and the data of the wave received in the step (5).

10 5. The method of claim 1, wherein the characteristic value to be detected in the steps (6) and (7) is a height of a wave appearing in a predetermined position in the composite wave.

15 6. The method of claim 1, wherein the characteristic value to be detected in the steps (6) and (7) is a height of a highest wave in the composite wave.

20 7. The method of claim 1, wherein the characteristic value to be detected in the steps (6) and (7) is an integral value of an absolute value of the composite wave.

25 8. The method of claim 1, wherein the characteristic value to be detected in the steps (6) and (7) is an integral value of absolute values of wave components in a period predetermined within a period from a first wave component to a tenth wave component of the composite wave.

9. The method of claim 1, wherein the characteristic value to be detected in the steps (6) and (7) is an integral value of an absolute value of a highest wave of the composite wave.

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10. The method of claim 1, wherein the first upstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element and the first downstream side shock wave-receiving piezoelectric element serves as the second downstream side shock wave-generating piezoelectric element.

11. The method of claim 1, wherein the first downstream side shock wave-receiving piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element.

12. The method of claim 1, wherein the first downstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-generating piezoelectric element.

13. An apparatus for measuring a flow rate comprising a set of a first upstream side shock wave-generating piezoelectric element and a first downstream side shock wave-receiving piezoelectric element and a set of a second downstream side shock wave-generating piezoelectric element and a second upstream side shock wave-receiving piezoelectric element arranged on a surface of a tube

under such condition that the shock wave-generating piezoelectric element and the shock wave-receiving piezoelectric element of each set are arranged along a fluid-moving direction apart from each other at an equivalent distance; an electric voltage source connected to each of the shock wave-generating piezoelectric elements directly or via switching means, whereby applying an impulse voltage with steep rising edge or steep falling edge to each of the shock wave-generating piezoelectric elements; and a processing means connected to each of the shock wave-receiving piezoelectric elements directly or via switching means, whereby detecting waves received by the shock wave-receiving piezoelectric elements, preparing a composite wave from the detected waves, and detecting a predetermined characteristic value from the composite wave.

14. The apparatus of claim 13, wherein the first upstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element and the first downstream side shock wave-receiving piezoelectric element serves as the second downstream side shock wave-generating piezoelectric element.

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15. The apparatus of claim 13, wherein the first downstream side shock wave-receiving piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element.

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16. The apparatus of claim 13, wherein the first downstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-generating piezoelectric element.

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17. A method for measuring a flow rate of a fluid moving in a tube which comprises the steps of:

(1) preparing a flowmeter comprising a set of a first upstream side shock wave-generating piezoelectric element and a first downstream side shock wave-receiving piezoelectric element and a set of a second downstream side shock wave-generating piezoelectric element and a second upstream side shock wave-receiving piezoelectric element arranged on a surface of the tube under such condition that the shock wave-generating piezoelectric element and the shock wave-receiving piezoelectric element of each set are arranged along a fluid-moving direction apart from each other at an equivalent distance;

(2) causing movement of the fluid in the tube and, while the fluid is moving, an impulse voltage with steep rising edge or steep falling edge is applied to the first shock wave-generating piezoelectric element to generate a shock and transmit the shock through a wall of the tube into the moving fluid so as to produce a shock wave in the moving fluid;

(3) transmitting the shock wave through the moving fluid and receiving the transmitted shock wave by the first shock wave-receiving piezoelectric element through the wall of the tube to measure a period of time required for the transmission of the shock wave from the first

shock wave-generating piezoelectric element to the first shock wave-receiving piezoelectric element;

(4) while the fluid is moving, an impulse voltage with steep rising edge or steep falling edge is applied
5 to the second shock wave-generating piezoelectric element to generate a shock and transmit the shock through the wall of the tube into the moving fluid so as to produce a shock wave in the moving fluid;

(5) transmitting the shock wave generated in the
10 step (4) through the moving fluid and receiving the transmitted shock wave by the second shock wave-receiving piezoelectric element through the wall of the tube to measure a period of time required for the transmission of the shock wave from the second shock wave-generating pi-
15 ezoelectric element to the second shock wave-receiving piezoelectric element;

(6) obtaining a difference of the period of time measured in the steps (3) and (5) required for the transmission of the shock wave;

20 (7) preparing a relationship between a moving rate of the fluid and a difference of period of time required for transmission of shock wave from the shock wave-generating piezoelectric element to the shock wave-receiving piezoelectric element separately;

25 and

(8) comparing the period of time required for the transmission of shock wave obtained in the step (6) with the relationship obtained in the step (7), to calculate the flow rate of the fluid of the step (2).

18. The method of claim 17, wherein the voltage applied by the impulse voltage in the steps (2) and (4) is kept constant until the generation of the shock in the shock wave-generating piezoelectric element ceases.

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19. The method of claim 18, wherein the voltage applied by the impulse voltage in the steps (2) and (4) is constant until the shock wave-receiving piezoelectric element receives the shock wave in the steps (3) and (5).

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20. The method of claim 17, wherein the first upstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element and the first downstream side shock wave-receiving piezoelectric element serves as the second downstream side shock wave-generating piezoelectric element.

21. The method of claim 17, wherein the first downstream side shock wave-receiving piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element.

22. The method of claim 17, wherein the first downstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-generating piezoelectric element.

23. An apparatus for measuring a flow rate comprising a set of a first upstream side shock wave-generating

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piezoelectric element and a first downstream side shock wave-receiving piezoelectric element and a set of a second downstream side shock wave-generating piezoelectric element and a second upstream side shock wave-receiving piezoelectric element arranged on a surface of a tube under such condition that the shock wave-generating piezoelectric element and the shock wave-receiving piezoelectric element of each set are arranged along a fluid-moving direction apart from each other at an equivalent distance; and an electric voltage source connected to each of the shock wave-generating piezoelectric elements directly or via switching means, whereby applying an impulse voltage with steep rising edge or steep falling edge to each of the shock wave-generating piezoelectric elements.

24. The apparatus of claim 23, wherein the first upstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element and the first downstream side shock wave-receiving piezoelectric element serves as the second downstream side shock wave-generating piezoelectric element.

25. The apparatus of claim 23, wherein the first downstream side shock wave-receiving piezoelectric element serves as the second upstream side shock wave-receiving piezoelectric element.

26. The apparatus of claim 13, wherein the first downstream side shock wave-generating piezoelectric element serves as the second upstream side shock wave-generating piezoelectric element.